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Comparative assessment of the morphological traits of local maize (*Zea mays L.*) varieties upon exposure to varying rates of poultry manure

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ABSTRACT

Maize (*Zea mays L.*) is an important cereal crop in Sub-Saharan Africa. As a pliable food source, increasing its yield to maintain a steady supply is of high importance. Poor soil fertility is a major factor contributing to low maize yield in Africa. Consequently, this work aimed to assess how varying poultry manure quantities impact the morphological growth and yield of two maize varieties: white and yellow, at the research farm of the Faculty of Agriculture, University of Nigeria, Nsukka. This assay involved a 2x4 factorial laid out in a Completely Randomized Design (CRD), performed 3 times. Poultry manure was applied in these amounts: 5t/ha, 10t/ha, 15t/ha, and 0t/ha (control). The experimental field consisted of 24 plots (8 plots triplicated) with 2 seeds per stand sown at a 4cm depth. Data collected included plant height, leaf length, width, number, and stem girth. These data were subjected to analysis of variance (ANOVA) using Genstat, with p-values ≤ 0.05 considered statistically significant. Poultry manure at 10t/ha showed significant $p \leq 0.05$ interactions for the number of leaves and leaf width per plant relative to other treatment levels, indicating better maize growth. The control had the lowest growth traits and the highest percentage of moisture loss. Based on the results, a recommendation of poultry manure application at 10t/ha should be used to achieve sustainable and higher maize production. This is due to the observation that 10t/ha of poultry manure yielded the best overall performance. Finally, yellow maize outperformed white maize at 10t/ha and is more responsive to yield upon application of 10t/ha of poultry manure.

Contribution/ Originality: This study is unique because it primarily reveals that among the two common maize varieties, yellow maize shows the strongest yield and growth response to poultry manure, making it the most effective variety for boosting maize production under poultry manure fertilization.

1. INTRODUCTION

Maize (*Zea mays*) is a very important cereal crop in sub-Saharan Africa, where it is used as a staple food to combat hunger and malnutrition [1]. Maize is the most abundantly produced cereal crop globally [2]. It is grown on every continent except Antarctica. About 50 species exist and consist of different colors, textures, and grain shapes and sizes. White, yellow, and red maize are the most common cultivated maize types. The white and yellow maize varieties are preferred by most people, depending on the region [3]. Maize, which was domesticated in central Mexico around 1500 BC, was introduced into Africa around 1500 AD and spread to every corner of the continent within a relatively short period. Maize is likely the most important cereal crop in sub-Saharan Africa (SSA) [4] and a staple food for more than 1.2 billion people both in SSA and Latin America [5]. More than 300 million Africans depend on maize as one of the main staple food crops [6]. All parts of the crop can be used for food and non-food products. Maize is also consumed as a vegetable, and it is rich in dietary fiber and other nutrients [7]. Maize accounts for 30–50% of low-income household expenditures in Africa [3]. It was previously shown that over 30% of the caloric intake of people in sub-Saharan Africa comes from maize [8]. For these reasons, several African countries that depend on maize as a staple food crop have adopted agricultural policies to maintain a steady supply of the commodity through increased production and productivity of the crop; however, the required amount for food security is not enough. Maize production in Africa was around 75 million tons in 2018, representing 7.5% of world maize production [9]. Maize occupies approximately 24% of farmland in Africa, and the average yield stagnates at around 2 tons/hectare/year [10]. The largest African producer is Nigeria with over 33 million tons, followed by South Africa, Egypt, and Ethiopia. However, Africa imports 28% of its required maize grain from countries outside the continent, as most of the maize production in Africa is done under rain-fed conditions [10].

In many developing countries, such as Nigeria, maize is eaten as a staple food and is the first cereal to be harvested every year at the green stage. Every part of the maize plant is important; the grains can be consumed, roasted, baked, fried, pounded, or cooked as porridges and used in weaning babies. It is also an important source of industrial products like corn sugar, porridges, beverages, bread, and snacks. Maize is a major component of livestock feed, and it is palatable to poultry, cattle, and pigs. The stalks, leaves, and immature ears are cherished by livestock.

Due to its importance in Nigeria, the area under maize production has increased over the years from about 438,000 ha in 1981 to over 3.3 million ha in 2009.

However, despite the increase in area under maize production in Nigeria, the amount produced cannot meet the demand for it. This is related to low yield, as the yield of maize in Nigeria is generally low, being about 1.4 $t\,ha^{-1}$ compared with the world average of 5.5 $t\,ha^{-1}$ and the USA of 9.5 $t\,ha^{-1}$. One of the major problems of the low harvest of maize in Nigeria is that of inherently poor soil. Poor soil fertility is the major cause behind low crop yield, including maize [11]. One way of increasing the yield per unit area of soil is by the addition of external inputs, including organic and chemical fertilizers [12].

Maize is a nutrient-demanding crop, and therefore, adequate and balanced nutrient supply is important for its growth and production. The use of chemical fertilizer has been reported to increase crop yields, but in Nigeria, its use is limited by high cost, scarcity during the planting season, soil acidity, and nutrient imbalance [13]. Because of these issues, the use of organic manure like poultry manure (PM) has been found useful in increasing crop production. Poultry manure is cheap, readily available at all times, environmentally friendly, and has a residual effect and the ability to improve soil structure compared with chemical fertilizers [14, 15]. It contains N, P, K, and other essential elements. Poultry manure application increases soil N by more than 53%, while exchangeable cations are also increased significantly upon application [16].

The rate of poultry manure applied may also influence the amount of nutrients released, soil chemical properties, growth, and yield of maize [17, 18]. However, poultry manure is limited by the large quantities required for large-scale maize production. Therefore, to address this problem, there is strong advocacy for integrating organic and inorganic fertilizers. For maize that requires large amounts of N for growth and yield, the use of poultry manure with urea fertilizer can be very beneficial. A positive interaction has been reported to occur between organic manure and urea as N sources.

However, Adekiya et al. [16] reported that using indigenous available organic nutrient sources can enhance efficiency and reduce the quantity of chemical fertilizer required [16, 17]. Apart from enhancing nutrient use efficiency, integrated nutrient use also maintains soil health, enhances yield, and reduces production costs [19].

For integrated nutrient management in maize cultivation, poultry manure is usually applied to the prepared soil two weeks before planting maize to allow the mineralization of the poultry manure [3]. The objective of this study was to investigate the effect of different rates of poultry manure on the morphological growth and yield of maize.

2. MATERIALS AND METHODS

2.1. Study Location

The experiment was conducted at the teaching and research farm of the Faculty of Agriculture, University of Nigeria, Nsukka. The study area is at a latitude of 6°52'N, a longitude of 07°, and an altitude of 447m above sea level. The experimental site is in the Derived Savannah zone of the southeastern ecology. The climate is humid-tropical, characterized by distinct seasons: wet season (usually April to October) and dry season (usually November to March). The mean annual rainfall of the area is about 1600mm, with a bimodal pattern of rainfall distribution, usually showing peaks in July and September [20]. The mean minimum and maximum temperatures are 29°C and 31°C, respectively [21]. Relative humidity can vary yearly, often within the range of 55% to 90% [10].

2.2. Experimental Design and Treatments

Experiment: To determine the response of white and yellow local maize varieties to poultry manure application. The experiment was a 2x4 factorial laid out in a Completely Randomized Design (CRD) [22] with three (3) replications. Two factors were studied.

Factor A (Varieties).

a_1. White Maize.

a_2. Yellow Maize.

FACTOR B (Manure Rates) in metric tons/hectare (t/ha).

b_1. Control (0t/ha).

b_2. Poultry manure (5t/ha).

b_3. Poultry manure (10t/ha).

b_4. Poultry manure (15t/ha).

Table 1. Poultry treatment design for maize varieties.

a_1	$b_1=a_1b_1$ (White maize + 0t/ha)
	$b_2= a_1b_2$ (White maize + 5t/ha)
	$b_3=a_1b_3$ (White maize + 10t/ha)
	$b_4=a_1b_4$ (White maize + 15t/ha)
a_2	$b1=a_2b_1$ (Yellow maize + 0t/ha)
	$b2=a_2b_2$ (Yellow maize + 5t/ha)
	$b3=a_2b_3$ (Yellow maize + 10t/ha)
	$b4=a2b_4$ (Yellow maize + 15t/ha)

2.3. Treatment Combinations

2.3.1. Planting and Spacing

The white and yellow maize were planted uniformly on the same date. Planting was done in the evening at a spacing of 0.85cm between the rows. Seeds were sown at a depth of 4cm at the rate of two (2) seeds per hole.

2.4. Weed Management

Weed control was done manually by hand-picking as and when necessary.

2.5. Application of Poultry Manure

Poultry manure was applied to the soil two weeks before planting as per the treatment imposed. Thus, control bags b_1 received no manure, bags labeled b_2 received 5t/ha of poultry manure, bags labeled b_3 received 10t/ha of poultry manure, and bags labeled b_4 received 15t/ha of poultry manure.

2.6. Irrigation

Watering was occasionally done with watering cans, and when necessary, depending on the prevailing climatic and soil moisture conditions.

2.7. Experimental Materials

White and yellow maize varieties were sourced from a reputable seed store at Ogige Market, Nsukka, Enugu State. Poultry manure was obtained from the poultry unit of the Animal Science Farm, University of Nigeria, Nsukka.

2.8. Media Preparation

Media preparation comprising substrate topsoil, poultry manure, and river sand in a 3:2:1 ratio was properly mixed and watered a day before planting. The maize seeds were also soaked overnight before planting.

2.9. Soil Sampling and Poultry Manure Analysis

Prior to planting, soil samples were collected from the fields at a depth of 0-20cm (topsoil) and taken to the Department of Soil Science lab for determination of soil pH, N, P, K, and other nutrients, as well as to determine the appropriate manure (poultry) to be applied.

2.10. Data Collection

Data were collected on the following parameters: Plant height (cm): This was obtained by measuring the plant from the base to the tip using a measuring tape. Number of leaves: This was done by visually counting the green leaves of white and yellow maize. Length of leaf (cm): This was determined by measuring from the distal to the proximal end of the longest leaf using a measuring tape. Width of leaf (cm): This was determined by measuring the widest leaf of the maize plant with a measuring tape.

2.11. Data Analysis

The data collected were subjected to analysis of variance (ANOVA) according to the procedure outlined for factorial in a Completely Randomized Design (CRD) [22]. Treatment means were compared using Fisher's least significant difference (F-LSD) at a 5% probability level. Statistical analysis was performed using GENSTAT.

3. RESULTS

The results presented in Table 1 exhibit the values of some soil properties and poultry manure composition prior to the experiment. The soil is quite basic, with a pH in K (0.08).

Table 2 presents the physicochemical components of the soil prior to and after planting. Table 3 exhibits the measured physiochemical and nutrient properties of the poultry manure used in this study.

Table 2. Soil physiochemical properties before and after planting.

Period	N%	P%	K%	Ca%	Mg%	Fe%	Zn%
Before planting	0.07	0.03	0.01	0.08	0.06	0.01	0.04
After planting	0.08	5.6	0.13	1.4	0.6	0.41	0.17

Table 3. Physiochemical and nutrient properties of organic manure (poultry manure) used for the study.

N%	P%	K%	Ca%	Mg%	Fe%
1.331	0.431	0.46	0.84	0.039	0.29

3.1. Main Effects of Variety and Manure Rates on Vegetative Growth and Yield of Local Maize Varieties Used in the Study

Plant height, number of leaves, leaf length, leaf width, and stem girth at specific growth stages are measured. The results on the main effects of variety and manure on maize plant height are presented in Table 4. The table shows significant differences in both variety and manure. In the variety table, yellow maize had higher values in all measured weeks, with 7.7cm, 10.9cm, and 20.0cm recorded for weeks 2 to 6, respectively. Conversely, the white maize variety recorded lower values across all weeks. Table 4 also displays the manure, poultry-manured pots, which recorded higher values across the weeks compared to the control.

The results presented in Table 5 show that yellow maize had a higher value regarding leaf length from week 2 through week 6, while the white maize variety had the lower mean value across the studied weeks. Significant differences were observed in weeks 4 and 6, but there was no significant difference in week 2.

The effect of manure in this table indicated that poultry manure had the higher mean value across the weeks (2-6), with the lowest being the ones without treatment or control. However, there were significant differences among the manure rates used.

Table 6 exhibits the main effect of variety and manure on maize leaf width. The effect of variety was shown on white maize, which had the highest value across the weeks.

Data in Table 6 also shows that there were no significant differences across the week. In the manure effect, the table indicated that poultry manure had a higher mean value across the weeks. Furthermore, Table 6 shows that at weeks 2 and 4, there were significant differences among the manure, but in week 6, there were no significant differences between the manure applied.

The main effect of variety and manure on the number of leaves of maize is seen in Table 7.

Yellow maize had the highest mean value as a variety in the number of leaves over the weeks (weeks 2-6). The effect of manure was observed in bags that received poultry manure throughout all measured weeks, with the lowest in bags without manure. Significant differences between variety and manure were noted, except in week 2.

Table 8 shows the stem girth of maize varieties in response to manure application at 2, 4, and 6 weeks post-planting. Of the two maize varieties, the yellow maize shows a relatively higher stem girth in response to poultry manure application.

Table 9 presents the main effect of variety and manure on the stem girth of maize. The table shows that the yellow maize variety had the highest mean value of stem girth during the 6 weeks, and the white maize variety had the lowest mean value. The manure effect in the table shows that poultry manure gave the highest value, with control being the lowest. However, there were significant differences among the varieties and the manures used in this study.

Table 4. Main effect of variety and Manure rates on plant height (cm) of maize from weeks 2-6 after planting.

Plant height (cm)			
Variety	**Week 2**	**Week 4**	**Week 6**
White	5.7	9.0	18.7
Yellow	7.7	10.9	20.0
F- LSD	1.4	1.1	NS
Manure rates			
Control	5.0	7.7	17.0
5 Tons	9.3	8.7	17.8
10 tons	6.9	12.7	22.6
15 tons	5.6	10.6	20.0
F- LSD(0.05)	**2.0**	**1.6**	**1.8**

Note: F-LSD= Fischer's least significant difference, WK= Week.

Table 5. Main effect of variety and Manure rates on Leaf length (cm) of maize from weeks 2-6 after planting.

Variety	Week 2	Week 4	Week 6
White	25.2	50.0	68.0
Yellow	28.6	53.1	70.6
F- LSD	NS	2.8	2.1
Manure rates			
Control	20.1	38.3	56.3
5 Tons	25.4	53.6	70.5
10 tons	32.9	59.2	76.5
15 tons	29.2	55.1	73.9
F- LSD(0.05)	**6.32**	**4.08**	**2.99**

Note: F-LSD= Fischer's least significant difference, WK= Week.

Table 6. Main effect of variety and Manure rates on Leaf width (cm) of maize from weeks 2-6 after planting.

Variety	Week 2	Week 4	Week 6
White	1.6	2.5	5.1
Yellow	1.5	2.5	5.0
F- LSD	NS	NS	NS
Manure rates			
Control	1.4	2.2	4.23
5 Tons	1.5	2.5	5.0
10 tons	1.6	2.7	5.7
15 tons	1.6	2.5	5.4
F- LSD(0.05)	**0.19**	**0.21**	**NS**

Note: F-LSD= Fischer's least significant difference, WK= Week.

Table 7. Main effect of variety and Manure rates on Number of Leaves of maize from weeks 2-6 after planting.

Variety	Week 2	Week 4	Week 6
White	4.9	10.5	19.4
Yellow	5.5	11.7	20.1
F- LSD	NS	NS	NS
Manure rates			
Control	3.8	9.1	15.1
5 Tons	4.5	10.6	18.8
10 tons	6.6	13.0	23.0
15 tons	6.0	11.8	22.1
F- LSD(0.05)	**1.1**	**1.2**	**1.0**

Note: F-LSD= Fischer's least significant difference, WK= Week.

Table 8. Main effect of variety and Manure rates on Stem girth (cm) of maize from weeks 2-6 after planting.

Variety	Week 2	Week 4	Week 6
White	0.3	0.9	2.0
Yellow	0.3	1.0	2.2
F- LSD			
Manure rates			
Control	0.17	0.5	1.6
5 Tons	0.37	1.0	2.2
10 tons	0.47	1.3	2.5
15 tons	0.43	1.1	2.3
F- LSD(0.05)	0.05	0.31	0.29

Note: F-LSD= Fischer's least significant difference, WK= Week.

3.2. Interaction Effects of Variety and Manure Rates on Growth of Maize Varieties Used in the Study

Table 9 presents the interaction effect of manure and variety on the plant height of yellow maize. The results presented in the table it shows that the yellow maize bag, which received poultry manure, recorded a higher mean value across the weeks, but the white maize bag that received poultry manure had a lower mean value compared with other interactions. However, there were significant differences among the varieties and manure.

The results of the effect of manure and variety on leaf length are shown in Table 10. The table indicates that the yellow maize variety, which received poultry manure, had higher mean values of 8.94cm, 5.7cm, and 4.2cm from weeks 2-6 studied. The white maize variety, receiving the same rate of poultry manure, had the lowest values. Significant differences across the weeks were observed.

Table 11 presents the interaction effect of manure and variety on the leaf width (cm) of maize at weeks 2-6 after planting. The white maize variety that received poultry manure had a higher mean value for leaf width across the studied weeks, with the lowest in the yellow maize variety that received similar poultry manure levels. However, manure rates and maize varieties were statistically different from each other.

The results on the effect of manure and variety on leaf number are presented in Table 12. The table shows that the yellow maize variety receiving poultry manure had the highest mean leaf number. Notwithstanding, there were significant differences between the variety and the manure applied across the weeks.

The result presented in Table 13 shows that the yellow maize variety receiving levels of poultry manure had high mean values in all the weeks studied. The results below indicate that the yellow maize variety had a higher mean stem girth across the weeks, with the white maize variety having the lowest mean value.

Conclusively, there were no significant differences among the interactions in week 2, but there were significant differences between their interactions.

Table 9. Interaction effect of manure and variety on the Plant height (cm) of maize at weeks 2-6 after planting.

Plant height (cm)				
Variety	**Manure rates**	**WK 2**	**WK 4**	**WK 6**
White	Control	4.1	6.9	16.8
White	5	4.6	7.8	17.4
White	10	9.1	12.3	22.0
White	15	5.0	8.9	18.6
Yellow	Control	5.9	8.5	17.2
Yellow	5	6.6	9.6	18.27
Yellow	10	9.4	13.2	23.2
Yellow	15	8.9	12.4	21.5
F-LSD(0.05)		2.8	2.2	2.6

Note: F-LSD = Fischer's least significant difference, WK = Week.

Table 10. Interaction effect of manure and variety on the Leaf length (cm) of maize at weeks 2-6 after planting.

Leaf length (cm)				
Variety	**Manure rates**	**WK 2**	**WK 4**	**WK 6**
White	Control	18.5	37.8	56.4
White	5	22.9	51.2	66.6
White	10	33.7	58.9	76.7
White	15	25.9	52.0	72.2
Yellow	Control	21.7	38.8	56.2
Yellow	5	28.0	56.0	74.5
Yellow	10	32.1	59.9	76.1
Yellow	15	32.5	58.2	75.6
F-LSD(0.05)		8.94	5.7	4.23

Note: F-LSD = Fischer's least significant difference, WK = Week.

Table 11. Interaction effect of manure and variety on the Leaf width (cm) of maize at weeks 2-6 after planting.

Leaf width (cm)				
Variety	**Manure rates**	**WK 2**	**WK 4**	**WK 6**
White	Control	1.4	2.4	4.3
White	5	1.5	2.4	5.0
White	10	1.7	2.7	5.7
White	15	1.6	2.6	5.6
Yellow	Control	1.3	2.1	4.1
Yellow	5	1.5	2.5	5.1
Yellow	10	1.6	2.7	5.8
Yellow	15	1.6	2.5	5.3
F-LSD(0.05)		0.2	0.3	0.3

Note: F-LSD = Fischer's least significant difference, WK = Week.

Table 12. Interaction effect of manure and variety on the Number of leaves of maize at weeks 2-6 after planting.

Number of leaves				
Variety	**Manure rates**	**WK 2**	**WK 4**	**WK 6**
White	Control	3.3	8.3	14.3
White	5	4.0	10.0	18.3
White	10	6.6	12.6	23.3
White	15	5.6	11.3	21.6
Yellow	Control	4.3	9.1	16.0
Yellow	5	5.0	10.6	19.3
Yellow	10	6.6	13.0	22.6
Yellow	15	6.3	11.8	22.6
F-LSD(0.05)		1.6	1.7	1.4

Note: F-LSD = Fischer's least significant difference, WK = Week.

Table 13. Interaction effect of manure and variety on the Stem girth (cm) of maize at weeks 2-6 after planting.

Variety	**Manure rates**	**WK 2**	**WK 4**	**WK 6**
White	Control	0.1	0.5	1.6
White	5	0.3	0.8	2.0
White	10	0.4	1.2	2.4
White	15	0.4	1.0	2.3
Yellow	Control	0.1	0.6	1.7
Yellow	5	0.4	1.2	2.4
Yellow	10	0.5	1.3	2.6
Yellow	15	0.4	1.0	2.3
F-LSD(0.05)		NS	0.4	0.4

Note: F-LSD = Fischer's least significant difference, WK = Week.

4. DISCUSSION

Different types of agricultural practices are needed to increase maize growth yields and components [23]. This is because the soil of arable land areas has very low organic content and is nutrient-deficient [24].

From the results, significant differences in the growth of maize show that there were distinctive features in the two varieties used in the experiment. Yellow maize recorded higher in the growth component of the study, which could be related to differences in nutrient uptake, transport within the plant, or nutrient use efficiency.

The performance of different rates of poultry manure used in this experiment could be attributed to its nutrient composition. Poultry manure is known to be rich in organic matter and essential plant nutrients [15, 25]. These nutrients are released slowly over time as the organic matter decomposes, providing a continuous supply of nutrients to the plants. It was shown that poultry manure can enhance soil fertility and microbial activity, promoting overall plant growth and development [26]. This could explain why plants treated with poultry manure performed better than those without it. The highest number of leaves, plant height, increase in leaf length, and steady growth in response to 10t/ha of poultry manure provided adequate nitrogen, which is associated with high photosynthetic activity and vigorous vegetative growth. The results from the study showed that poultry manure supplementation was well accepted and beneficial to the maize varieties assessed. It was observed that the yellow maize variety performed significantly better than the white maize. These interactions led to increased plant height, number of leaves, leaf length, leaf width, and stem girth, resulting in faster growth. Therefore, adding poultry manure to the soil can improve soil structure, regulate soil pH, enhance water retention, and release nutrients, all of which benefit the growth and yield of both white and yellow maize varieties.

5. CONCLUSION

The research suggests that using poultry manure as a soil amendment promotes the growth, morphology, and yield-related traits of maize plants. Poultry manure, when added to soil, helps improve physical and chemical properties such as nitrogen, potassium, phosphorus, and soil organic matter. The morphological growth attributes of both maize varieties studied were significantly enhanced in soil amended with poultry manure compared to the control. The study revealed that poultry manure applied at 10 t/ha yielded better results for maize crop production, indicating it is more effective and beneficial for soil property improvement. However, the optimal application rate likely varies depending on soil type and climate.

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